Among bars of the latter kind, it was found that it was only in the case of bismuth and antimony that the compound bar conducted heat according to the calculated amount.

May 26, 1859.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

The following communications were read :—

I. "On the Intimate Structure, and the Distribution of the Blood-vessels, of the Human Lung." By A.T.H. WATERS, Esq., Lecturer on Anatomy and Physiology, Liverpool. Communicated by Dr. SHARPEY, Sec. R.S. Received April 7, 1859.

Having been recently engaged in investigating the anatomy of the human lung, I beg to lay before the Royal Society some of the results of my observations with respect to the arrangement of the ultimate air-tubes and the distribution of the blood-vessels of the organ.

The bronchial-tubes of the lungs, after several divisions and subdivisions, which for the most part are of a dichotomous nature, terminate in a dilatation, into which open a number of elongated cavities, which constitute the ultimate expressions of the air-tubes. These elongated cavities, to which various names have been given, I propose to call *air-sacs*, as being, in my opinion, more appropriate to their shape and arrangement than any term hitherto used; and the series of air-sacs connected with the extremity of each bronchial twig, with its system of blood-vessels, &c., I shall call a *lobulette*.

Every lobule of a lung is composed of a number of lobulettes, and thus the description of a single lobulette will suffice for that of the entire lobule.

Each lobulette consists of a collection of air-sacs, which vary in number from six to eight, ten or twelve. The air-sacs are somewhat elongated cavities, communicating with the dilated extremity of a bronchial tube by a circular opening, which is usually smaller than the sac itself, and has sometimes the appearance of a circular hole in a diaphragm, or as if it had been punched out of a membrane which

had been stretched across the entrance to the sac. When this is the case, the sac dilates suddenly beyond the opening. The sacs of the lobulette are placed side by side, and are separated from each other by thin membranous walls. Their shape, when properly inflated, or when distended by some material which has set in them, as gelatine, or a mixture of wax and turpentine, is polygonal. They approach the circular form, but in consequence of their mutual pressure, the parietes become somewhat flattened. The sacs increase slightly in size as they pass from the bronchial tube to their fundus, the latter being usually the broadest part of the sacs; but they often have an almost uniform diameter throughout. All the sacs pass from the extremity of the bronchial tube *towards* the circumference of the lobule of which the lobulette forms a part; they consequently radiate from the tip of the bronchial twig. The sacs connected with one lobulette do not communicate with those of another lobulette. As the sacs pass towards the boundary of the lobulette, they often bifurcate; and here and there circular orifices exist, leading to smaller air-sacs, sometimes only to a small group of "air-cells," or *alveoli*. If we trace the air-sacs from their fundus, we may say that, passing from the periphery of the lobulette, and diminishing somewhat in size, they all terminate in the dilated extremity of the bronchial tube; as they thus proceed they often join two or three together, and these terminate in a single mouth. The tube which results from the union of two or more sacs, is smaller in capacity than the sacs taken together, but greater than either of them individually. The dilated extremity of the bronchial tube above alluded to constitutes the "point de réunion" of all the air-sacs, and may be considered as the common centre of the lobulette.

The walls of which the air-sacs are composed are exceedingly thin, and much sacculated, *i. e.* they have in them a number of small, shallow, cup-like depressions, separated from each other by portions of membrane which are more or less raised and project into the interior of the sac. The bottom of the air-sac presents the same appearance as the lateral walls; and the cup-like depressions, or *alveoli*, are there very numerous. The number of these alveoli varies very much; I have counted as many as ten at the fundus of an air-sac in a cat's lung; in the human lung I have counted five and six, but the number is not usually quite so great. Close to the bottom

in some of the air-sacs in the human lung, a circular opening, similar to those already alluded to as leading to other sacs, small and constricted, is often seen, and has the appearance as if it led to another sac; on examination, however, it will be found to be produced by a projection inwards of the membrane of the sac, and to lead to a small cavity, or group of alveoli.

The number of alveoli existing in the air-sacs varies—Rossignol states that each "infundibulum" (air-sac) contains from ten to twenty alveoli. My own observations entirely accord with this statement. I have found the number varying from eight to twenty.

The air-sacs externally, by their fundus, rest on the pleura, but within the substance of the lung they in part rest on, and are supported by, the bronchial tubes and blood-vessels.

The air-sacs are separated from each other by thin walls, the membrane composing which, in a lung inflated and dried, is very transparent. The projection of this membrane in the shape of a thin process, having a sharp margin, constitutes the septa between the alveoli; and wherever an opening exists leading into a smaller sac, this membrane projects in a similar way, and forms a circular orifice which is much smaller than the cavity to which it leads:—the sac, in fact, dilates abruptly on the distal side of the opening. It is in the membrane composing these walls, and in the septa of the alveoli, that the capillaries of the pulmonary artery are spread out.

The number of air-sacs belonging to a lobulette varies: I have counted as many as six communicating with a bronchial tube incised horizontally, so that probably only half the sacs were left; this, however, is a larger number than is usually found; from six to eight or ten is the more common number.

Each lobulette is separated from those by which it is surrounded, by walls which appear to resemble in every way the walls of the air-sacs; and in an adult inflated and dried lung, careful observation is necessary to make out the partitions. That perfect septa do exist, is proved by laying open, in a recent lung, a bronchial tube to its ultimate division, when by placing a fine blowpipe in it, and blowing down it, a single lobulette is alone inflated.

The separation of the lobulettes is further distinctly perceptible in the recent lungs of infants, in which the line of demarcation between the lobulettes is often plainly seen, on the surface.

The observation of the fœtal lung, however, affords most satisfactory evidence of the separation of the lobulettes, and tends to confirm the views here taken of the arrangement of the ultimate air-tubes.

The recent lung of a full-grown fœtus presents on its surface no appearance of air-sacs, or vesicles, or cells; but if it be inflated, it will present different appearances, according as the inflation has been partial or entire. In a portion of lung only partially inflated, a number of tubes will be seen terminating beneath the pleura in cæcal extremities, their light colour contrasting strongly with the surrounding dark-coloured tissue. The exact arrangement of these tubes may be sometimes seen. They will be found to exist in groups or clusters, and are seen to pass from the cæcal ends to a point, in which they terminate, and where they all appear to join; or, to describe them in the inverse direction, they pass from a point at some distance from the surface, and radiate towards the pleura. The tubes are seen to have numerous constrictions and bulgings; they terminate in extremities rounded, or nearly so. In a preparation of this kind it is often easy to see the bronchial tube for a short distance before it terminates; and not only is the terminal group of air-sacs (lobulette) visible, but two or more of the previous ones arising laterally from the bronchial tube may be also seen. The uninflated lung-substance lying between the distended air-sacs is distinctly seen when there has been only slight inflation; and the isolated condition of each group of sacs is very apparent; the sacs passing from different points are seen radiating in different directions. In a lung which has been fully inflated, the grouped appearance is lost, and the ordinary condition of the distended lung is observed.

If, in a fœtal lung, we follow out a bronchial tube, we find that the smaller branches of the tube have connected with them clusters of little pyriform red-coloured bodies, which look very much like a number of grapes attached to their stalks. In a fœtus of six months I have found it somewhat difficult to separate each individual body, but in a full-grown fœtus there is no difficulty in doing so; each little body is attached to a short pedicle. If air be blown down a bronchial tube leading to the exposed bodies, the latter become distended.

The little bodies just described are the ready-formed groups of air-sacs, or lobulettes; the pedicle with which each is connected is

the terminal bronchial twig. The lobulette thus formed is surrounded by its sheath, and no communication exists between it and adjoining ones.

That the appearances I have described in the artificially inflated fœtal lung are not the result of any abnormal distension, I have been able to prove by observing the same appearances in the lung of a child in which only partial respiration had taken place.

Do the air-sacs communicate with each other by any orifices except that by which they communicate with the bronchial tube?

Different opinions have been expressed on this point. Adriani states that he has observed such orifices, and specially mentions that they are most clearly to be seen in the stag. Dr. Thomas Williams considers that the "intercellular passages" intercommunicate, and are perforated by secondary passages at every point. Rossignol, Schultz, Mandl, and Milne-Edwards, deny the existence of such communications. From observations, made with much care and frequently repeated, I have satisfied myself that the opinion expressed by the latter authors is correct. I have never found, either in the lung of man or in that of the dog, cat, pig, sheep, or any other mammal I have examined, any lateral orifices of communication between the sacs of a lobulette.

Alveoli of the Bronchial Tubes.—The termination of the bronchial tubes has a special character, first pointed out by Rossignol. He says, "In the bronchial divisions of the two last, and sometimes three last orders, it is plainly seen, when they are opened longitudinally, that their surface is covered over, or, as it were, honeycombed with a number of small, regular, shallow cavities, placed side by side, and separated by thin perfect walls of the same height, which project into the interior of the bronchial tube." The existence of these bronchial alveoli has been noticed by subsequent observers; they may be easily seen in a lung injected and inflated, and sometimes even in one which has been simply soaked in spirit for a few days; they resemble the alveoli of the air-sacs; they are best seen in the lungs of some of the lower animals, as the cat, in which they are found in the ultimate bronchial tubes and their dilated extremities. In man I have never seen them, except at the extremity of the tubes; and in many lungs I have found no appearance of them at all—they appear to become obliterated with advancing age. In the

infant I have found them in the last divisions of the bronchial tubes, and their dilated extremities, but not in the penultimate or earlier branches; and even in the last divisions they are not always present previous to the dilatation. In respect of the extent, therefore, to which these alveoli exist in the human lung, my observations do not quite accord with those of Rossignol.

The Blood-vessels of the Lungs.—The branches of the pulmonary artery accompany the bronchial tubes, arrived at the extremity of which, they give off branches to the bronchial alveoli, and terminate in vessels which take their course in the walls of the air-sacs in no very definite or regular manner. From these vessels the pulmonary plexus arises.

The pulmonary veins, receiving the blood from the plexus of the air-sacs, pass from the periphery of the lobulettes, and running in the spaces between the lobules, make their way, independently, to the root of the lung.

The pulmonary plexus is situated in the walls which separate the air-sacs, in the septa of the alveoli, and around the margins of the openings which exist in the sacs. The plexus consists of a single layer of vessels, which, as already pointed out by Mr. Rainey, is in no instance doubled on itself. In the septa of the alveoli, and in the margins of the orifices alluded to, the plexus does not reach quite to the free border of the membrane composing them.

There is no distinct and separate vessel for each alveolus, but the branches of the terminal artery take their course along the walls of the air-sacs, and give off branches which for the most part run in the septa of the alveoli; some of them, however, pass across the alveoli. From these vessels, and from the branches first mentioned, the capillary plexus arises. The plexus, when formed, maintains a tolerably uniform size throughout. In a well-injected preparation, inflated and dried, it will be seen that the spaces between the vessels are somewhat greater in diameter than the vessels themselves.

The branches of the pulmonary artery do not anastomose till they reach the termination of the bronchial tubes; on the air-sacs they anastomose freely. It is somewhat difficult to decide whether the vessels of one lobulette anastomose with those of another. On looking at a preparation injected and dried, it seems as though the septum, separating one lobulette from another, resembled in every

respect the walls of the air-sacs; but as the lobulettes are originally separate and independent bodies, as seen in the fœtal lung, it is probable that the vessels of each are distinct. If so, there must be, where the walls of two lobulettes are in contact, two layers of capillaries lying side by side; and from the mode of formation of the lobulettes, and from the fact that I have been able, in some preparations of the adult lung, partially to separate the lobulettes from one another, I believe that their vessels are distinct, that they terminate in their proper radicle-vein, and that thus the capillaries on the outer wall of the lobulette are only exposed on one side to the atmosphere.

The Bronchial Vessels.—It has long been held that the bronchial arteries are distributed to the air-tubes, the areolar tissue, and the vessels of the lungs, and that they pour their contents *partly* into the pulmonary veins, and *partly* into certain deep bronchial veins, which have been described by most anatomists as accompanying the arteries within the lungs. An opinion has also been entertained that a communication exists between the bronchial vessels and the branches of the pulmonary arteries. Without referring to the experiments and results of other observers, I proceed to state my own.

My observations have been made on the lungs of the cat, the dog, the rabbit, the pig, the calf, and the sheep, as well as on those of man. The following remarks have special reference to the results obtained in the human lung.

When the pulmonary artery is injected so that the fluid reaches the pulmonary plexus but does not pass to any extent into the pulmonary veins, the blood-vessels of the bronchial mucous membrane and of the other portions of the bronchial tubes *never* become injected. When, however, the injection is continued so as to fill the pulmonary veins, the vessels of the bronchial tubes become partially injected.

When the pulmonary veins are injected, whether the pulmonary plexus be well-filled or not, the vessels of the bronchial tubes and of the bronchial mucous membrane are always injected. The bronchial tubes are often seen to be injected when the pulmonary plexus is only very partially so, the fluid seeming to find its way from the pulmonary veins into the vessels of the bronchial tubes more readily than into the capillaries of the air-sacs.

When a bronchial artery, as it enters the substance of the lung, is injected, the vessels of the bronchial tubes become filled—both those of the mucous membrane and of the deeper portions—and the fluid finds its way into the pulmonary veins. If the injection be continued, it is easy to inject the pulmonary plexus through the medium of the bronchial arteries; and injection is often found in the branches of the pulmonary arteries.

In injecting a bronchial artery in the human subject, I have always found that part of the bronchial tubes nearest the point of insertion of the injection pipe more fully injected, both as regards the mucous membrane and the deeper structures, than the parts situated towards the extremity of the tubes. I have found the larger branches injected nearly to the end of the tubes, but not the fine vessels of the mucous membrane. This seems to me to be due to the fact, that throughout the entire extent of the tubes there is so free a communication between the bronchial vessels and the pulmonary veins, that the fluid finds its way into the latter more readily than into the fine plexus of the extreme tubes.

The Bronchial Veins.—The examination of a large number of specimens, both of the lungs of man and the lower animals, and the injection of the vena azygos on several occasions, have not enabled me to find the so-called deep bronchial veins, as *venæ comites* of the bronchial arteries. I have always found a small vein or veins, generally a single one, situated at the posterior aspect of the bronchus, and terminating, as shown by the injection, in the structures of bronchus, lower part of trachea, and glands at the root of the lung, but not passing along the bronchial tubes *within* the lung, and therefore being in no way concerned in returning the blood distributed to those parts by the bronchial arteries.

A piece of human lung well injected by the bronchial artery, exhibits on the mucous membrane of the bronchial tubes, a fine plexus of vessels, taking for the most part a longitudinal direction; under these other vessels are found, which run transversely beneath the elastic tissue, in the direction of the muscular fibres; these deeper vessels are larger than the superficial ones; there is a distinct communication between the two sets.

I now pass to consider *in what manner*, and *where*, the communi-

cation which undoubtedly exists between the pulmonary and bronchial vessels, takes place.

If the statement I have made with reference to the bronchial veins be true, those vessels do not return the blood supplied by the bronchial arteries, except so far as the latter vessels distribute it to the bronchi themselves and the structures about the root of the lung; and the next point we have to examine is whether any communication exist between the bronchial arteries and the pulmonary arteries. In all the best injections I have made, whether in man or the lower animals, in which the injection was introduced by the pulmonary artery, I have never found the vessels of the bronchial tubes injected unless the pulmonary veins were well-filled, and in such specimens I have *seen* vessels passing from the bronchial tubes, and joining a branch of a pulmonary vein. I have found branches of the pulmonary artery containing injection, when the latter has been introduced through the bronchial artery; but in such specimens I have found portions of the pulmonary plexus injected, and I believe the injection has found its way through the plexus into the pulmonary arteries. I have never seen the vessels described by some anatomists as passing from the pulmonary artery to the bronchial tubes.

With regard to the communication of the bronchial vessels with the pulmonary veins, it admits of ocular proof. It is unquestionably more easy to inject the vessels of the finer bronchial tubes through the pulmonary veins, than through the bronchial arteries at the root of the lung; it is also possible to inject those vessels to a certain extent through the pulmonary veins, without injecting the pulmonary plexus. On the other hand, the injection thrown in through the bronchial arteries rapidly and readily finds its way into the pulmonary veins. These facts seem to prove that the blood distributed by the bronchial arteries within the lung is poured into the pulmonary veins, and that the whole vascular system of the bronchial tubes communicates with the same veins.

It has been stated by Mr. Rainey, that the vessels of the bronchial tubes anastomose at the extremity of the tubes with the vessels of the "air-cells" (air-sacs). In this I cannot concur, for I have never been able to fill these extreme vessels by injection through the pulmonary artery. My belief is, that at the termination of the tubes,

as elsewhere, the blood of the bronchial arteries is poured into the pulmonary veins.

Dr. Heale has advanced the opinion that the bronchial arteries do not supply the bronchial mucous membrane at all, and that they neither communicate with the pulmonary arteries nor veins. My observations have given results entirely opposed to this view.

With reference to the view taken by Adriani, and subsequently adopted by Dr. Thomas Williams, that the vessels of the bronchial mucous membrane terminate in the pulmonary veins, and those of the deeper plexus in the bronchial veins, it is not borne out by the experiments I have made, which appear to prove that not only do the same vessels supply the superficial and deep plexuses of the tubes, but that both plexuses discharge their contents into the same receptacles.

II. "On Certain Sensory Organs in Insects, hitherto undescribed." By J. Braxton Hicks, M.D. Lond., F.L.S. &c. Communicated by John W. Lubbock, Esq. Received May 14, 1859.

(Abstract.)

The author commences with an allusion to papers published in the Linnean Society's 'Journal' and 'Transactions' respecting groups of organs, abundantly supplied with nerves, on the bases of the halteres of Diptera, also on the nervures of the wings and on the elytra of Coleoptera; and now gives a drawing which shows forth these organs, and the nerve proceeding to them on the halteres. He then describes, for the first time, somewhat similar organs on the apices of the palpi of some Diptera, and on their base in many Hymenoptera, as *Apis*, *Vespa*, *Nomada*, *Megachile*, *Bombus*, &c. These are well shown in the *Vespa Crabro*, or Hornet, where the nerve is seen expanding in the thin membrane which covers in the opening beneath in the wall of the member.

In the paper also, it is pointed out for the first time, that on the apex of the palpi of Lepidoptera there is invariably found a structure which is more or less of a cavity, generally tubular, and sometimes extending inwards nearly the length of the last segment, but some-